National Park Service
U.S. Department of the Interior

Northeast Region
Philadelphia, Pennsylvania

Survey of Mammals at Petersburg National Battlefield

Technical Report NPS/NER/NRTR--2005/027

ON THE COVER
Young Virginia opossum (*Didelphis virginiana*) at Petersburg National Battlefield, VA.
Photograph by: A. M. Roder and A. D. Chupp, Virginia Commonwealth University.

Survey of Mammals at Petersburg National Battlefield

Technical Report NPS/NER/NRTR--2005/027

Pagels, J. F., A. D. Chupp, and A. M. Roder

Department of Biology
Virginia Commonwealth University
1000 W. Cary St.
Richmond, VA 23284

November 2005

U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

The Northeast Region of the National Park Service (NPS) comprises national parks and related areas in 13 New England and Mid-Atlantic states. The diversity of parks and their resources are reflected in their designations as national parks, seashores, historic sites, recreation areas, military parks, memorials, and rivers and trails. Biological, physical, and social science research results, natural resource inventory and monitoring data, scientific literature reviews, bibliographies, and proceedings of technical workshops and conferences related to these park units are disseminated through the NPS/NER Technical Report (NRTR) and Natural Resources Report (NRR) series. The reports are a continuation of series with previous acronyms of NPS/PHSO, NPS/MAR, NPS/BSO-RNR, and NPS/NERBOST. Individual parks may also disseminate information through their own report series.

Natural Resources Reports are the designated medium for information on technologies and resource management methods; "how to" resource management papers; proceedings of resource management workshops or conferences; and natural resource program descriptions and resource action plans.

Technical Reports are the designated medium for initially disseminating data and results of biological, physical, and social science research that addresses natural resource management issues; natural resource inventories and monitoring activities; scientific literature reviews; bibliographies; and peer-reviewed proceedings of technical workshops, conferences, or symposia.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

This report was accomplished under Cooperative Agreement 4560C0042, Modification Number 001 with assistance from the NPS. The statements, findings, conclusions, recommendations, and data in this report are solely those of the author(s), and do not necessarily reflect the views of the U.S. Department of the Interior, National Park Service.

Print copies of reports in these series, produced in limited quantity and only available as long as the supply lasts, or preferably, file copies on CD, may be obtained by sending a request to the address on the back cover. Print copies also may be requested from the NPS Technical Information Center (TIC), Denver Service Center, PO Box 25287, Denver, CO 80225-0287. A copy charge may be involved. To order from TIC, refer to document D-92.

This report may also be available as a downloadable portable document format file from the Internet at http://www.nps.gov/nero/science/.

Please cite this publication as:

Pagels, J. F., A. D. Chupp, and A. M. Roder. November 2005. Survey of Mammals at Petersburg National Battlefield. Technical Report NPS/NER/NRTR--2005/027. National Park Service. Philadelphia, PA.

NPS D-92 November 2005

Table of Contents

Table of Contents (continued)

Figures

Page

Tables

Page

Appendixes

Page

Abstract

Petersburg National Battlefield (PETE) includes the 685 ha Eastern Front unit , located largely within the City of Petersburg, VA, and the 452 ha Five Forks unit, located in a rural setting in Dinwiddie County, VA. At both units we sampled mammals in field-forest edge, pine forest plantation, mixed pine hardwood, hardwood, and bottomland hardwood habitat types, plus a wetland habitat type at Five Forks; maintained fescue fields and agricultural fields were not sampled. Of the same 38 mammalian species that potentially occur at the PETE units sampled, we recorded 15 at Eastern Front and 19 at Five Forks sampling with several trap types, observations, and night-camera photography. Low numbers of captures and recaptures at both units prevented statistical analysis of differences in richness and relative abundance among habitat types. Among the few species of small mammals captured at Eastern Front the white-footed mouse (*Peromyscus leucopus*) was captured most often, followed by southern short-tailed shrew (*Blarina carolinensis*) and hispid cotton rat (*Sigmodon hispidus*). Based on captures and photographs, the Virginia opossum (*Didelphis virginiana*) was relatively abundant and the common raccoon (*Procyon lotor*) was very abundant at Eastern Front. Numerous night-camera photographs of the common gray fox (*Urocyon cinereoargenteus*) were also recorded at Eastern Front. Both richness and abundance of mammals were greater at Five Forks than Eastern Front. Among nine species of small mammals, hispid cotton rat-size or smaller, captured at Five Forks, the white-footed mouse was captured in greatest numbers, followed by the marsh rice rat (*Oryzomys palustris*), southern short-tailed shrew, and the southeastern shrew, (*Sorex longirostris*). Unlike Eastern Front, no fox species and very few common raccoons were captured or photographed at Five Forks; however, the coyote (*Canis latrans*) and the bobcat (*Felis rufus*) were recorded at Five Forks. Greatest relative abundance (numbers of individuals per unit effort) and species richness were found in field-forest edge and bottomland hardwood habitat types at Eastern Front and in field forest edge and wetland habitat types at Five Forks. There were no significant differences among mammals captured and the various habitat types at either unit. At Eastern Front and Five Forks, certain species were recorded by more than one method, by observations only, (i.e., eastern cottontail [*Sylvilagus floridanus*], American beaver [*Castor Canadensis*], and red fox [*Vulpes vulpes*]), or by night-camera photography only (i.e., the coyote and bobcat). These findings strongly support the use of multiple sampling methods when attempting to document a diverse mammal fauna. Fields form an integral part of the cultural landscape at Eastern Front and Five Forks, however maintenance of exotic fescue grass fields is likely detrimental to many mammal species and other wildlife. Conversion of fescue fields to fields more characteristic of secondary succession is encouraged to benefit mammals and other wildlife. The Eastern Front is strongly influenced by human activities and will present ongoing challenges in wildlife management because of the park's popularity to visitors and because it is much like an island in a residential and commercial setting. Included among special challenges that are familiar to the NPS in many regions, and that may necessarily require involvement of state and federal agencies to be resolved, are high populations of raccoon, white-tailed deer (*Odocoileus virginianus*), and roaming pet and feral domestic house cats (*Felis catus*).

Executive Summary

Two units of the Petersburg National Battlefield (PETE), the Eastern Front and Five Forks, were surveyed to establish a baseline inventory of non-volant mammalian species during sampling in 2003 and 2004. The 685 ha Eastern Front is located in the upper Coastal Plain, and Five Forks, comprising 452 ha, is located approximately 32 km southwest of Eastern Front in the lower Piedmont. The Eastern Front enjoys high levels of visitation and is nearly encircled by commercial and residential development. Both units are characterized by fields of fescue grasses (*Festuca spp*) and a mosaic of forested successional habitat types ranging from pine forests to hardwood forests. We sampled in five major habitat types (field-forest edge [FFE], pine forest plantation [PFP], mixed pine hardwood [MPH], hardwood [HWD], and bottomland hardwood [BLHWD]) at both units and also in a wetland habitat type (WD) at Five Forks. Maintained fields and agricultural fields were not sampled. Mammals were sampled using several trap types and sampling was augmented by observations and night-camera photography. Sampling was completed along a transect in the narrow field-forest edge habitat type and in a circular plot in the other habitat types. Of the 38 species of mammals that potentially occur at PETE, 15 species were documented at Eastern Front and 19 at Five Forks. Our findings support the importance of using multiple sampling methods in surveys. Many shrews and other small mammals were captured in pitfall traps, most mouse-sized rodents were captured in small live traps, medium-sized mammals, such as the common raccoon and Virginia opossum, were captured in large live traps, and many medium and large mammals were documented by observation or night-camera photographs. Overall trapping success was low during the survey. Because of a low number of recaptures we could not statistically test whether differences in richness and relative abundance were significantly different among habitats at either unit. Only seven species (exclusive of domestic cat captures) were captured at Eastern Front. The usually very abundant white-footed mouse, a habitat generalist, was captured in greatest number among mammals, however its numbers were relatively low compared to findings in similar studies completed by us in central Virginia during the same period. Conversely, numbers of the common raccoon at Eastern Front, both in captures and in night-camera photographs, as well as photographs of the common gray fox, were very high. Based on observations, the numbers of white-tailed deer are very high. In addition to greater overall mammal species richness at Five Forks, more mammal species were captured in traps at Five Forks (12 species) than at Eastern Front (seven species). Nine species, hispid cotton rat-size or smaller, were captured and included the pygmy shrew, one of the world's smallest mammals. Unlike at Eastern Front, the white-footed mouse was very abundant as based on captures, and the common raccoon was very uncommon as based on captures and night-camera photographs at Five Forks. Neither the red fox nor the common gray fox were recorded at Five Forks. Two large predators, the bobcat and the coyote, were photographed at Five Forks. At both Eastern Front and Five Forks very little old field habitat characteristic of secondary succession is present; instead, the maintained and agricultural fields are dominated by fescue grasses. Mammal species, and wildlife in general, would likely benefit if fescue fields, or at least some of them, were converted to warm-season grasses. Our findings indicate a relatively rich mammal fauna at Five Forks. The low richness and abundance of mammals at Eastern Front presumably reflects the park's popularity to visitors and could be because much of Eastern Front is like an island in a residential and commercial setting. The unit's popularity and setting will present ongoing challenges in wildlife management. These challenges, familiar to the NPS in many regions and that may necessarily involve local, state, and federal agencies to be resolved,

include high populations of raccoon, white-tailed deer, and roaming pet and feral domestic house cats. Lists of numbers of mammals that occur at both units could be increased if a protocol was developed for park personnel to report and assist in the documentation of mammals that they observe or find in the parks. Further, we suggest that future sampling should be directed toward a particular group or habitat type. Such sampling can be more intense and completed in a shorter time period and likely require fewer sampling methods.

Introduction

The National Park Service has established the Inventory and Monitoring Program (I&M) to gather existing and new information about natural resources in the parks and to make that information easily available at different levels to park resource managers, the scientific community, and the public. For park managers to effectively maintain the biological diversity and ecological health of their parks, they must have a basic knowledge of what natural resources exist in parks, as well as an understanding of those factors that may threaten them. One of the first goals of the I&M Program has been to establish baseline biological inventories for vascular plant and vertebrate species in order to provide reliable species lists which are fundamental tools for management.

This report presents the results of a baseline non-volant mammal inventory conducted at two units of the Petersburg National Battlefield; the Eastern Front, located largely within the City of Petersburg, VA, and Five Forks, located in Dinwiddie County, VA. The primary project objective was to document 90% of mammals, excluding bats, by confirming the existence of species known from the park units and documenting the presence of new species. Excluding marine and domesticated species, 78 mammal species occur in Virginia (Linzey 1998). Based on distributional maps in Handley and Patton (1947), Linzey (1998), and Webster et al. (1985), 38 species are thought to occur at both Eastern Front and Five Forks. The species listed are the same for both units, a reflection of the close geographical proximity of the units. The NPSpecies (2005) database lists no species for the two units. We were unable to find in the literature any evidence of earlier study or collection of mammals at Eastern Front or Five Forks. We found no museum records of mammals designated as having been collected within either unit, although some specimen records are available for counties surrounding both Eastern Front and Five Forks.

Reconnaissance, identification of habitat types, and selection and layout of sampling sites were completed in spring 2003. Data collection was conducted over a 14-month period from June 2003 to August 2004. The study objectives were to 1) document 90% of mammal species, exclusive of bats, that occur within the boundaries of Eastern Front and Five Forks; 2) document habitat-specific species abundance and richness to shed light on the importance of habitat types to mammals; 3) evaluate factors that impact sampling success and explore the use of multiple sampling techniques within the constraints of feasibility; and 4) provide park staffs with conservation and management recommendations.

Study Areas

Eastern Front Unit

The Eastern Front unit of Petersburg National Battlefield is primarily located within the city limits of Petersburg, in Prince George County, VA, and is bounded on the east by Fort Lee, a U.S. military installation. The unit lies within the Coastal Plain physiographic region immediately east of the fall line (the juncture of the Coastal Plain and Piedmont physiographic regions). The average elevation at Eastern Front is approximately 30.5 m (100 ft). The Eastern Front covers an area of 585 ha (1,445 ac) that includes fields of fescue grasses (*Festuca spp*) and a mosaic of forested successional habitat types ranging from pine forests to hardwood forests. A one-way tour road, numerous recreational trails, and a highway bisect portions of the unit. Earthen remnants of Civil War activity as well as remnants from more recent training sites for World War I are evident in many areas. Roughly 90% of the unit is forested and contains a relatively even mix of deciduous and coniferous species. The western edge of the unit contains the only fields and those are maintained (mowed) to preserve the cultural landscape. In addition, there are several creeks that meander through the park. Areas surrounding Eastern Front are somewhat rural only on the eastern boundary where it abuts Fort Lee. Otherwise, as a result of the park's popularity (~150,000 visitors/yr.) and surrounding commercial and residential development, mammal species within the park are presumably strongly influenced by human activities.

Five Forks Unit

The Five Forks unit of Petersburg National Battlefield is located in Dinwiddie County approximately 32 km (20 mi) southwest of the Eastern Front unit. Five Forks is located in the eastern portion of the Piedmont physiographic region just west of the fall line and has an average elevation of approximately 69 m (226 ft). The unit covers approximately 452 ha (1,117 ac) and similar to Eastern Front, it includes fields of fescue grasses and a mosaic of successional habitat types ranging from pine forests to hardwood forests. Approximately 90% of Five Forks is wooded with young coniferous stands dominating the forested landscape. Hatchers Run, located in the northeastern section of the unit, is the source of a modest lake, associated wetlands, and a beaver pond. Agricultural and otherwise maintained (mowed) fields comprise only a small portion of the park. However, natural old field habitat does not exist within the unit. Five Forks, unlike Eastern Front, is surrounded by a rural setting that includes agricultural activity, forests of various ages, and scattered residences that are characteristic of much of present-day south-central Virginia.

Methods

Development of Potential Species List

The potential species list was based on a literature search, a museum records search, and more than 35 years of personal experience working on Virginia mammals (John F. Pagels). Among the literature sources, we relied heavily on Linzey (1998, and personal communication), who searched hundreds of collections as part of his recent effort on *The Mammals of Virginia*. Table 1 provides a list of the 38 mammals that may occur at Eastern Front and Five Forks and the literature that was searched. We found no museum records of mammals designated as having been collected within either unit, although some specimen records are available for surrounding counties. Primary collections contacted were the National Museum of Natural History, Carnegie Museum of Natural History, Virginia Museum of Natural History (which includes the Virginia Tech Mammal Collection), Virginia Commonwealth University Mammal Collection, North Carolina State Museum of Natural History (which includes the former George Mason University collection and University of Kentucky collection), Shippensburg State University Vertebrate Collection, and the University of Memphis Mammal Collection.

Site Selection

In fall 2002, with the initial help of natural resource manager, Tim Blumenschine, and aerial photographs, we determined the available habitat types and scouted possible sampling sites within each habitat type. Five major habitat types were sampled at Eastern Front: field-forest edge (FFE), pine forest plantation (PFP), mixed pine-hardwood (MPH), hardwood (HWD), and bottom land hardwood (BLHWD). At Five Forks sampling was completed in those habitat types as well as a wetland (WD) habitat type. Although we had not planned to sample the field-forest edge (edge) habitat type, we did because of the abundance of edge situations and the likely impact of that habitat type on mammal presence.

Sample locations were randomly selected using a grid system, but in most cases required re-location in the field to ensure that the samples were located in an area representative of the selected habitat type. Three sampling sites (replicates) were established in each of the habitat types, except the BLHWD at Five Forks which had only two replicates (15 sampling sites total at Eastern Front and 17 at Five Forks). Boundaries of all sampling sites within the habitat types were at least 300 m apart, usually much more, and at least 30 m from the edge of the given habitat type. These minimum distances were typically dictated by the patchy distribution of habitat types. We did not trap for mammals in the actual fields because of potential conflict with maintenance practices (mowing) and agricultural contractors. Both in early reconnaissance trips and later during the survey we were unable to find signs (i.e. runways, scats, or cuttings) that would indicate the presence of small mammals (except for moles) in the maintained or agricultural fields.

Sampling points in each of the habitat types are indicated on Figure 1 for Eastern Front and Figure 2 for Five Forks. GPS coordinates for all sampling sites, excluding FFE sites, were taken using a Trimble TSC1 (Trimble Navigation Limited, Sunnyvale, CA) with NAD83 datum. GPS coordinates for the FFE sampling sites were taken using a Magellan GPS 315 (Magellan

Table 1. Potential mammal species that may occur in Petersburg National Battlefield's Eastern Front and Five Forks units.

Common Name	Scientific Name[a]	Literature[b]
Virginia opossum	*Didelphis virginiana*	1,2,4,8,3
pygmy shrew	*Sorex hoyi*	1,4,6,8
southeastern shrew	*Sorex longirostris*	1,2,4,6,8
northern short-tailed shrew	*Blarina brevicauda*	2,3
southern short-tailed shrew	*Blarina carolinensis*	1,2,4,6,7,8
least shrew	*Cryptotis parva*	1,2,4,6,8,3
eastern mole	*Scalopus aquaticus*	1,2,4,8,3
star-nosed mole	*Condylura cristata*	1,2,4,6,8
eastern cottontail	*Sylvilagus floridanus*	1,2,4,8,3
eastern chipmunk	*Tamias striatus*	1,2,4,8
woodchuck	*Marmota monax*	1,2,4,8,3
eastern gray squirrel	*Sciurus carolinensis*	1,2,4,8,3
fox squirrel	*Sciurus niger*	4
southern flying squirrel	*Glaucomys volans*	1,2,4,8
American beaver	*Castor canadensis*	1,2,4,8,3
marsh rice rat	*Oryzomys palustris*	1,2,4,8,3
eastern harvest mouse	*Reithrodontomys humulis*	1,2,4,8,3
white-footed mouse	*Peromyscus leucopus*	1,2,4,8
golden mouse	*Ochrotomys nuttalli*	2,4,8
hispid cotton rat	*Sigmodon hispidus*	2,4,6,8,3
Norway rat	*Rattus norvegicus*	1,2,8
black rat	*Rattus rattus*	1,2,3
house mouse	*Mus musculus*	1,2,8,3
meadow vole	*Microtus pennsylvanicus*	1,2,4,8
woodland vole	*Microtus pinetorum*	1,2,4,8,3
common muskrat	*Ondatra zibethicus*	1,2,4,8,3
meadow jumping mouse	*Zapus hudsonius*	1,2,4,8
coyote	*Canis latrans*	1,4,8
red fox	*Vulpes vulpes*	1,2,4,8,3
common gray fox	*Urocyon cinereoargenteus*	1,2,4,8
common raccoon	*Procyon lotor*	1,2,4,8,3
long-tailed weasel	*Mustela frenata*	1,2,4,8
least weasel	*Mustela nivalis*	1,6
American mink	*Mustela vison*	1,2,4,8,3
striped skunk	*Mephitis mephitis*	1,2,4,8,3
northern river otter	*Lontra canadensis*	1,2,4,8
bobcat	*Felis rufus*	1,2,4
white-tailed deer	*Odocoileus virginianus*	1,2,4,5,8,3

[a] Nomenclature follows:

Jones et al. 1997.

[b] Literature:

1. Bellows 2001a.
2. Handley and Patton 1927.
3. Jackson et al. 1976.
4. Linzey 1998.
5. NPSpecies 2005.
6. Pagels Unpublished Information.
7. Pagels and French 1987.
8. Webster et al. 1985.

Figure 1. Map depicting the location of mammal sampling sites within the Eastern Front unit of Petersburg National Battlefield, Petersburg, Virginia, inventoried during 2003 and 2004.

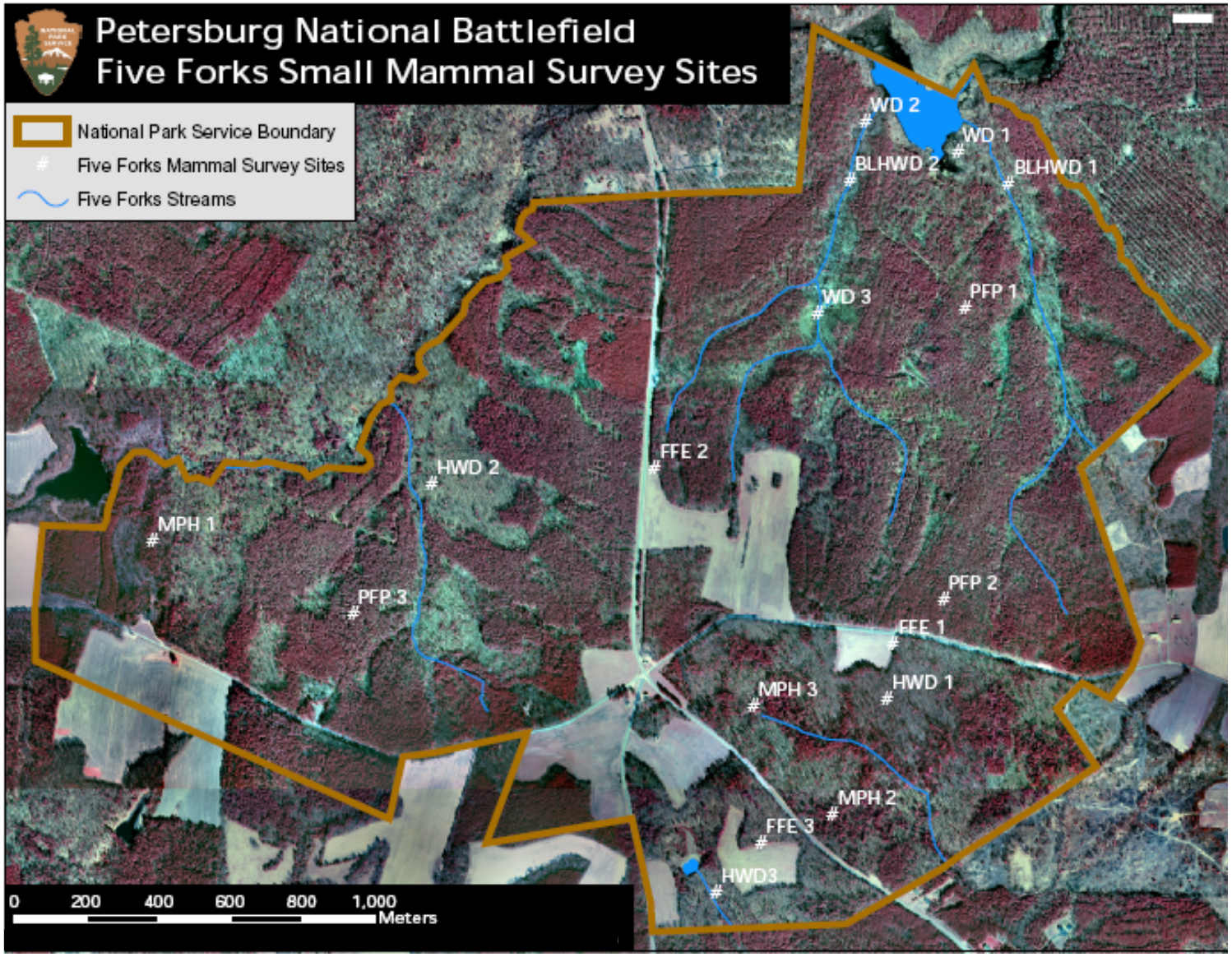

Figure 2. Map depicting the location of mammal sampling sites within the Five Forks unit of Petersburg National Battlefield, Dinwiddie County, Virginia, inventoried during 2003 and 2004.

Corporation, San Dimas, California) with NAD27 datum and were converted to NAD83 for development of the site maps.

All coordinates are Universal Transverse Mercator (UTM), Zone 18, and are provided in Appendix A.

Habitat Types

Below is a brief description of vegetation at each of the habitat types. Relative basal area for tree species within each habitat type is given in Appendix B. Slight variations in plant assemblages between some of the habitat types of the two units are provided in the descriptions.

Field-forest Edge (FFE)

In nearly all situations at both units field maintenance or mowing created very abrupt or narrow contact areas along the field and forest edges. In most areas the edge habitat type was only one to five meters wide. Vegetation along field-forest edges was typically a mix of field and forest vegetation and much more heterogeneous than in the field or forest. This habitat type contained both pine and deciduous species in the overstory. Conifer species included loblolly pine (*Pinus taeda*) and red cedar (*Juniperus virginiana).* Deciduous species were variable among sites but included black cherry (*Prunus serotina*), sweetgum (*Liquidambar styraciflua)*, red maple (*Acer rubrum*), white oak (*Quercus alba*), and red oak (*Quercus rubra*). Also common at Eastern Front were willow oak (*Quercus phellos)* and hackberry (*Celtis occidentalis).* The understory was comprised of saplings of overstory species. However, the understory was often dominated by shade-intolerant pioneer species such as red cedar. Shrubs were also common in the understory with sumac (*Rhus sp*) and multiflora rose (*Rosa multiflora*) being the most abundant. Vines present in this habitat type often included Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Rhus radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and common greenbriar (*Smilax rotundifolia*). Herbs and grasses (non-native fescue) were more common here than in other habitats.

Pine Forest Plantation (PFP)

Pine plantations were dominated by loblolly pine and, although age was not measured, it was estimated that these stands were 20 to 25 years in age. When young these stands can be very thick, but the stands we sampled had begun a natural thinning process and at most sites the understory was becoming more open than in less mature stands. These stands were also characterized by a thick carpet of pine needle litter. The understory of this habitat type was comprised of deciduous tree species such as blackgum (*Nyssa sylvatica*), tulip poplar (*Liriodendron tulipifera*), red maple, black cherry, sweetgum, red oak, white oak, and American holly (*Ilex opaca*). Oak species were less common and red cedar was more common at Eastern Front than at Five Forks. Nearly all understory trees in this habitat type were small (DBH [diameter at breast height] < 10 cm). Vines were more frequent in this habitat than other habitats. The most common species were common greenbriar, Japanese honeysuckle, poison ivy, and Virginia creeper. Vines combined with shrubs and small deciduous saplings often formed thicket-like growth. Although grasses and herbs were relatively uncommon here, the invasive species Japanese stiltgrass (*Microstegium vimineum*) was present in this habitat type.

Mixed Pine Hardwood (MPH)

The MPH habitat type included both deciduous trees and pine trees in the overstory and understory. This habitat type is considered to be an intermediate successional stage between pine and hardwood forest. Loblolly pine was the only conifer present in this habitat type. Although deciduous trees were more abundant than loblolly pine in the overstory, the DBH of loblolly pine was considerably larger (i.e., there were fewer pine than deciduous trees, but the pines were larger). The most common deciduous trees in the overstory included tulip poplar, sweetgum, red maple, white oak, red oak, and species of hickory. Common subcanopy species included American holly, blackgum, hackberry, and dogwood (*Cornus florida*). Understory tree species were mostly saplings of overstory species. However, as expected in this successional stage, deciduous saplings were more common than pine saplings. Vine and shrub communities were similar to those described in the pine plantation habitat type.

Hardwood (HWD)

The hardwood forest habitat type was characterized by various deciduous species in the overstory and understory. Common overstory species included red maple, tulip poplar, sweetgum, blackgum, white oak, red oak, and hickories. Subcanopy species included sassafras (*Sassafras albidum*), American holly, dogwood, and red cedar. Understory tree species were mostly saplings of overstory species. Although no conifers were recorded at Eastern Front, loblolly pines are sparsely scattered among hardwood stands at both units. In fact, six loblolly pines (average DBH = 22 cm) were recorded at one HWD sampling site in the Five Forks unit. Vegetative analyses later revealed that the DBH of trees ranged from approximately 9 cm in subcanopy trees to 35 cm among oak species. Ground cover consisted primarily of deciduous leaf litter. Herbaceous, grass, and shrub growth were relatively sparse in the HWD habitat types. Viny growth was infrequent in the HWD habitat type.

Bottomland Hardwood (BLHWD)

The BLHWD habitat type was largely restricted to floodplain situations near streams. At the Five Forks unit, both BLHWD sites were located along streams that fed Hatchers run. Overstory trees at both units were primarily deciduous species. At both units the most common deciduous species were American sycamore (*Platanus occidentalis*), ash (*Fraxinus spp*), birch (*Betula spp*), red maple, tulip poplar, hackberry, and sweetgum. Common subcanopy tree species included American holly, blackgum, dogwood, and ironwood (*Carpinus caroliniana*). The understory was comprised of saplings of overstory species. The most common shrub in the understory was spicebush (*Lindera benzoin*). Vines present in this habitat type often included Japanese honeysuckle, poison ivy, Virginia creeper, and common greenbrier. Viny growth was minimal at Eastern Front but extremely abundant at Five Forks. At both units a variety of grasses and herbs were observed in much greater abundance here than at any other habitat type. At the Eastern Front unit the most common grass was the invasive species Japanese stiltgrass, and when present, the species dominated the forest floor. Switch cane (*Arundinaria gigantean*) was only present at BLHWD 1 in Eastern Front, but along with Japanese stiltgrass, it was extremely abundant. Ferns were also common in this habitat type at both units. With locations so close to water sources, BLHWD sampling sites had very moist substrates. Occasional washouts from flooding were not unusual at most of our BLHWD sampling sites.

Wetland (WD)

This habitat occurred only at the Five Forks unit. Two of these sampling sites were located along the fringe of Hatchers Run and one site was located south of Hatchers Run adjacent to a beaver pond (Figure 1). In each case, the substrate was very moist and standing water was always at least 20% of the ground cover. Overstory trees were primarily deciduous, and common species included red maple, hackberry, birch, sweetgum, tulip poplar, blackgum, white oak, and willow oak. The subcanopy often included American holly, ironwood, and alder (*Alnus spp*). The understory was comprised of saplings of overstory species as well as an abundance of shrubby growth. Spicebush and alder were the most abundant shrubs. Viny growth in this habitat type was similar to that of BLHWD. Shrubby growth combined with greenbrier and tree saplings produced almost impenetrable barriers. As in BLHWD grass and herbaceous growth were very abundant at these sites.

As noted above, Japanese stiltgrass was an obvious herbaceous component at a couple of our sampling sites at Eastern Front. However, Japanese stiltgrass was evident in many areas of Eastern Front and stands of the grass either encroached into our sampling sites or were evident nearby. Sites where the grass was observed included one PFP site, two FFE sites, two MPH sites, and all three BLHWD sampling sites. Japanese stiltgrass was not recorded in the HWD sites.

Survey and Collection Methodology

The circular-plot scheme used for our sampling sites at Eastern Front and Five Forks was modified from other studies. The scheme has been successfully used in studies on mammal population dynamics (Orrock et al. 2000), mammal communities (Bellows et al. 1999b, McShea et al. 2003), documenting presence of endangered species (Orrock et al. 2000), and determining new records of occurrence (Bellows et al. 1999a). Each circular sampling site consisted of a 30-m diameter circle with markers in the center and 15 m from the center in each cardinal direction (Figure 3). In this way, the site was divided into four equal quadrants. Three 7.6 x 8.9 x 22.9 cm (3" x 3.5" x 9") Sherman live traps (H. B. Sherman Traps, Tallahassee, Florida) were placed at likely capture spots within a 2-m radius extending toward the center from each cardinal direction. Two 40.6 x 12.7 x 12.7 cm (16" x 5" x 5") Tomahawk live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin) were placed in opposite quadrants from each other, and one 81.3 x 25.4 x 30.5 cm (32" x 10" x 12") Tomahawk live trap was placed at or near the center of the site. Sherman live traps were baited with an oatmeal/peanut butter mixture that was wrapped in wax paper and hung from inside the back door of the trap (small dabs of peanut butter were also placed on the open front door). Small Tomahawk traps were baited with apples covered in peanut butter. The large Tomahawk traps were baited with apples and sardines. Live traps typically underestimate the abundance of shrews, whereas pitfall traps are very efficient in capturing shrews, especially the smallest species (Mitchell et al. 1993, Kirkland and Sheppard 1994). In order to more effectively sample smaller mammals such as shrews, two pitfall traps were placed in each of the sites' four quadrants. Natural drift fences (i.e., fallen logs and stumps) and 533 ml (16 oz) beverage cups filled with ~5 cm of water were used for all initial pitfall traps. Plastic mesh lids (15 cm x 15 cm) elevated by nails were used to shield the pitfall traps from falling leaves and other debris. Pitfall traps larger than those that we used are more

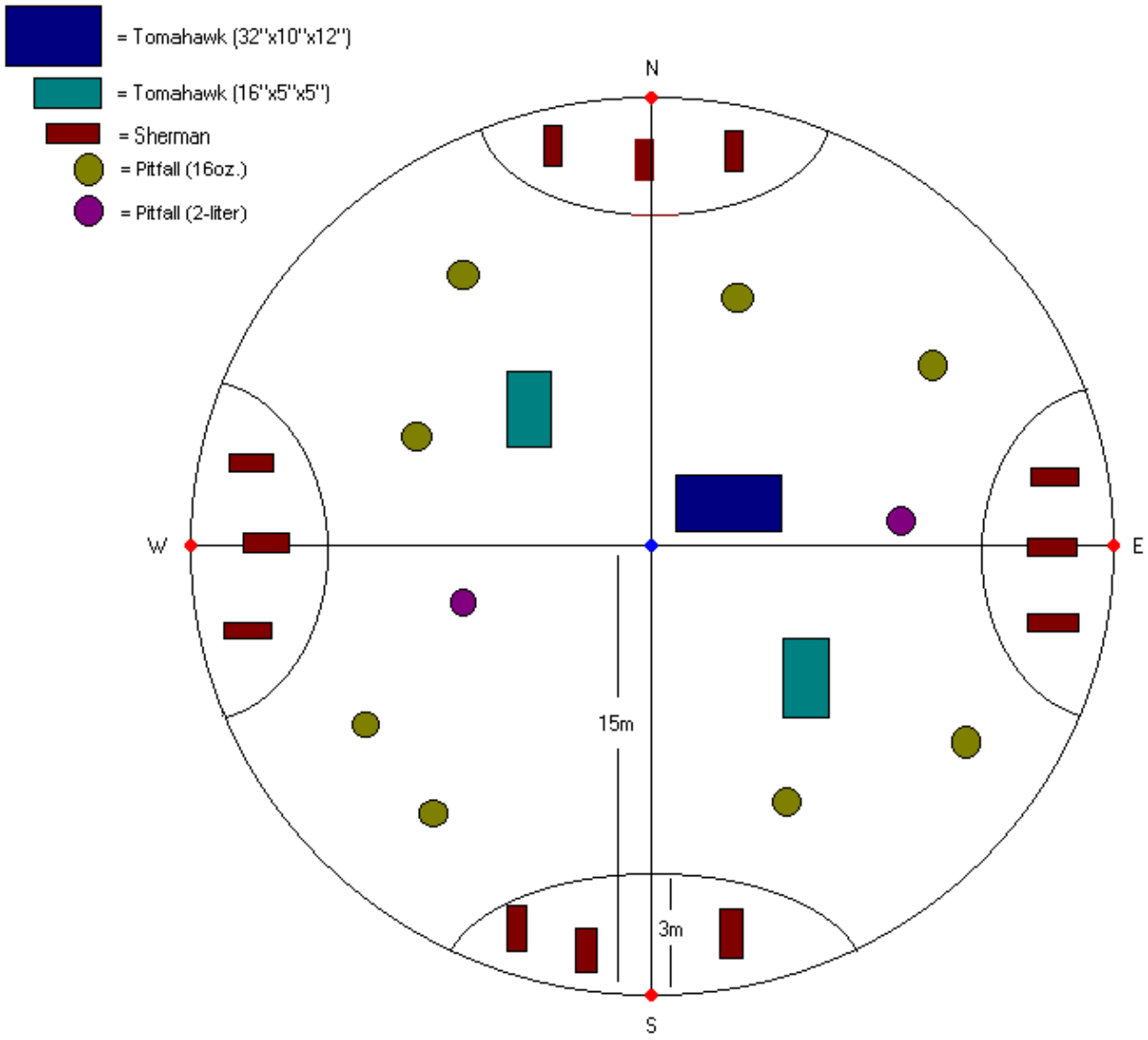

Figure 3. Mammal sampling configuration for circular plots used in the inventory of mammals at the Eastern Front unit, Petersburg, VA, and at the Five Forks unit, Dinwiddie County, VA of Petersburg National Battlefield.

effective for many small mammals (Mitchell et al. 1993); however, in initial discussions with NPS personnel at various sites we were encouraged to keep soil disturbance to a minimum at the historical sites. Because of poor capture success of shrews, two larger pitfall traps were added to each site for sampling in spring 2004. For these pitfall traps we used 2 L plastic bottles with the tops cut off (after Handley and Varn 1994). These larger traps required somewhat larger holes, however, soil disturbance at sampling sites remained minimal. In addition, we installed two or three drift fences made of steel mesh 0.6 cm (1/4") hardware cloth (two drift fences if a natural barrier was present). Like all traps, the two liter pitfall traps were placed at most likely capture spots (i.e., near coarse woody debris) whenever possible. All pitfall traps were closed by lowering the plastic mesh cover over the pitfall trap between sampling sessions (i.e., when sampling was not ongoing).

In order to more effectively sample the field-forest edge habitat type, transects were used instead of circular plots. The FFE habitat types were narrow and use of the circular arrangement would have overlapped, or not met our required minimum distance (30 m) to another habitat type. The sampling effort at transects as based on trap types and trap numbers was equivalent to that of the circular plots, but traps were arranged in a linear fashion (Figure 4) at most likely capture spots, generally within 2-4 m of the transect line.

Mammals the size of hispid cotton rats (*Sigmodon hispidus*) or smaller were tagged with Monel ear tags (National Band and Tag Co., Newport, Kentucky), weighed to the nearest gram, and examined for reproductive status and life history stage (i.e. adult, juvenile, etc.). Mammals the size of eastern gray squirrels (*Sciurus carolinensis*) or larger were marked on the dorsum with non-toxic spray paint and examined for distinguishable features and approximate age. The unique, but temporary marking allowed us to distinguish individuals captured in a single trapping session only. All animals were released at site of capture. Any deceased animals, for example all specimens captured in pitfall traps, were collected, stored in 70% propanol, placed on ice in the field, and are now frozen to serve as museum voucher specimens and as resources for additional studies. The frozen specimens are stored at Virginia Commonwealth University (VCU) in the VCU Mammal Collection. For all captures, we recorded the site of capture (i.e. HWD 1), trap type, and trap location. In circular plots, for pitfalls and small Tomahawks, we recorded the quadrant (i.e. NW) of the trap location, and for Sherman traps we recorded the cardinal direction.

In fall 2003 we began using night-camera photography as an additional method for documenting medium to large nocturnal species. We used TrailMaster's ActiveInfrared Trail Monitor (Model # TM1550) and Camera Kit (Model # TM35-1) (TrailMaster Infrared Trail Monitors, Lenexa, Kansas). Despite the initial costs of these instruments it has been shown that this method is appropriate for use in mammal inventories where larger mammals need to be surveyed (Silveira et al. 2003). Three cameras were used simultaneously within different portions of the units. During each trapping session, i.e., a fall or winter session (Appendix C), the cameras were active for the same number of nights as the trapping sites. Cameras were placed in areas most likely to be frequented by medium to large nocturnal mammals (i.e. wooded game trails and small dirt roads or walking paths) and where vegetation and topography would not trigger the trail monitors. Cameras were not located near the sampling sites, and camera location was varied

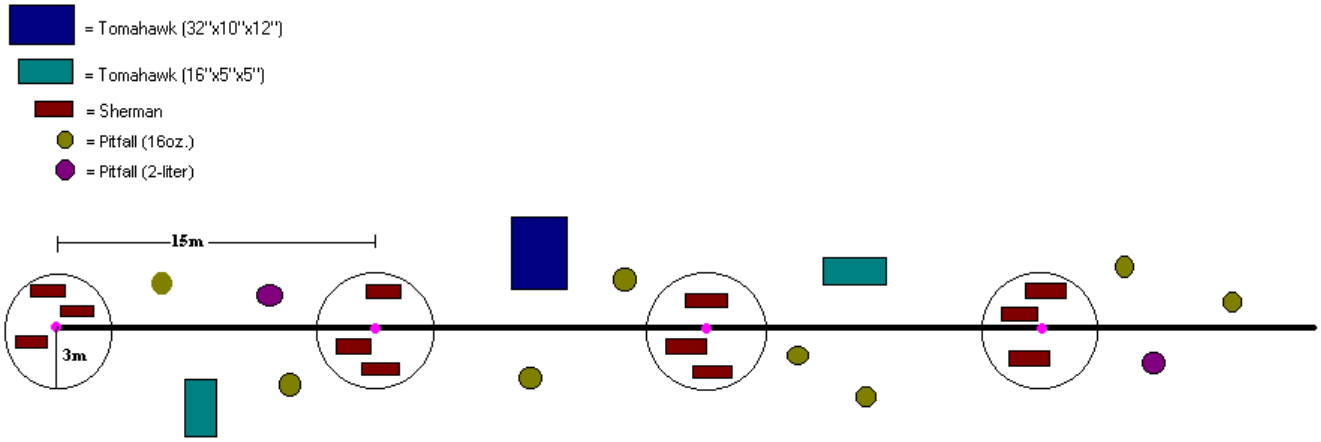

Figure 4. Mammal sampling configuration used for transects in field-forest edge habitat type at the Eastern Front unit, Petersburg, VA, and at the Five Forks unit, Dinwiddie County, VA of Petersburg National Battlefield.

among sampling sessions. Cameras were active from approximately dusk to dawn and were baited with sardines, peanut butter, apples, and chicken.

Trapping sessions were partitioned into seasons and occurred between June 2003 and August 2004. All habitat types within a unit were sampled at the same time, and all were sampled during each of the four calendar seasons. Trapping effort was greatest during the summer due to time constraints in fall, winter, and spring. Trapping session dates for Eastern Front and Five Forks and trapping effort with each trap type are given in Appendix C. Trapping effort within each habitat type of the two parks is given in Appendix D. Sometimes traps were sprung and had been moved about, likely the result of raccoon activity, and on those occasions a trapnight was subtracted from the effort (modified from Nelson and Clark 1973).

Site Analysis

Within trapping sites the diameter at breast height (DBH ~ 1 m) was recorded for all trees, defined as woody plants with a DBH ≥5 cm. For transect sites, any tree less than 5 m from the transect line was considered to be within the site. All trees with a DBH ≥5 cm were identified to species, except for those trees in the *Alnus, Betula, Carya, Fraxinus, Morus,* and *Ulmus* groups. Ground cover, substrate, and seedling composition were determined using the line-transect method of Canfield (1941). For circular sites, two 40 m transects were established that divided the sampling site into four equal quarters, bisecting in the center. For transect plots, the same 60 m transect line established for mammal sampling was extended by 10 m on each end. Eighty points were sampled for both types of plots at 1 m intervals. Using the line-transect method, we recorded observations in the following categories: herbaceous material, grass, leaf litter, bare soil, rock, woody debris, moss, lichen, shrub, and seedling. Rocks were sized as follows: size 1 < 0.2 m, size 2 = 0.2-0.4 m, size 3 = 0.41-0.8 m, and size 4 >0.8 m. We considered woody debris to be any portion of a woody stem or trunk regardless of the size. The diameter was recorded for any woody debris that was greater than 10 cm. Tree seedlings were defined as woody plants with a DBH <5 cm and were categorized as either hardwood or pine.

Data Preparation and Analysis

We used the number of unique (original, excludes recaptures) individuals captured (M_{t+1}; Slade and Blair 2000) as our metric of relative abundance for each species. The number of individuals captured (M_{t+1}) was corrected for trapping effort by dividing the number captured by the number of trapnights at each site for traps where a species could be captured (i.e., trapnights for the pygmy shrew were calculated using the number of pitfall traps only because this species is almost always only captured using this trapping method). The average relative abundance (± SE) was expressed per 100 trap nights.

Abundance estimated using M_{t+1} is an index of population size because the number of individuals captured is a function of population size as well as the likelihood that an individual will be captured (Slade and Blair 2000; Pollock et al. 2002). We use M_{t+1} because it performs as well as estimators that incorporate capture probability (i.e., the Lincoln-Petersen estimator) when captures are low and animals are not encountered among all habitats (Slade and Blair 2000), as was the case for many of the species we detected. Our estimates of relative abundance assume that capture probability does not differ among habitat types, trapping sessions, or types of traps

used where animals were captured. Although capture probability for the same species may vary depending upon these factors (Pollock et al. 2002), we do not present estimates of habitat-, season-, and trap-specific capture probabilities because the limited data for most of the species in our study was prohibitive (Pollock et al. 2002). Therefore, differences in relative abundance due to habitat, season, and trap-type were not compared statistically. Instead, average relative abundance (± SE) of each species is used only as an index of the population and as a baseline for more intensive future studies.

For each habitat type, we also calculated species richness and species evenness. Although species richness is defined as the number of species within a community (Wilson et al. 1996), we herein use it to define the number of species within each habitat type. Evenness was calculated using Shannon's index, where evenness varies from 0 for communities composed of a single species, to 1 for communities where all species are equally abundant (Zar 1999). Again, due to the low number of recaptures for most species, capture probabilities were not calculated and valid statistical inferences could not be made. Thus, these data were used only as indices of the populations.

Within each sampling site, the basal area of each tree (with a DBH ≥5 cm) was determined from its DBH. These values were combined to get a total basal area value for each species of tree found in the sampling site. Relative basal area was calculated by dividing the basal area for each tree species by the total basal area for the site and therefore represents the percentage of basal area within the site given by each tree species (Appendix B).

Results

Eastern Front Unit

Thirty-eight species of mammals potentially occur at Eastern Front based on known species distributions (Table 1). The current inventory documented 15 species representing approximately 40% of the species that potentially occur within Eastern Front (Table 2). None of the species documented are on State or Federal lists of species of concern. Night-camera photography and observations of mammals accounted for 8 of the 15 species recorded, i.e., 8 species that were not captured were otherwise documented. Based on observations, the white-tailed deer is very abundant at Eastern Front. The species and numbers of individuals recorded by each sampling method largely reflected the relative body size of the mammal (Table 3).

One hundred thirty-nine mammals were captured in traps at Eastern Front in 7,192 trapnights (Table 4). Although the numbers reflect initial captures (M_{t+1}) for most species, some of the larger forms of mammals (i.e. the Virginia opossum [*Didelphis virginiana*] and the common raccoon [*Procyon lotor*]) were marked to distinguish them in a given trapping session only, and some of the individuals are likely recaptures from earlier sessions. For each habitat type the relative abundance, i.e. the number of individuals captured (M_{t+1}) corrected for trapping effort, is given for each species in Table 5. The common raccoon had a high relative abundance in all habitat types sampled as based on captures (Table 5), and the species abundance was also indicated by high numbers of night photographs (Table 3). The relative abundance of the Virginia opossum was moderately high in all habitat types (Table 5). Conversely, the relative abundance of small mammals, shrew and mouse species, was relatively low in all habitat types.

Overall trapping success was low during the survey. Because of a low number of recaptures, we could not test whether differences in richness and relative abundance were significantly different among habitat types. The overall richness of species captured, seven, was also low. Only four species chipmunk size or smaller (eastern chipmunk [*Tamias striatus*], hispid cotton rat, white-footed mouse [*Peromyscus leucopus*], and southern short-tailed shrew [*Blarina carolinensis*]) were captured. Richness of species captured in the five habitat types ranged from seven in FFE to four in the PFP and MPH habitat types (Table 4). The number of mouse species captured differed among habitat types, with mouse species captured in the FFE and bottomland hardwood (BLHWD) habitats being greater than the number captured in MPH habitat.

Five Forks Unit

Thirty-eight species of mammals may also occur at Five Forks as based on known species distributions (Table 1). The current inventory documented 19 species, representing 50% of the species that may occur at the unit (Table 2). None of the species recorded for Five Forks are on State or Federal lists of species of concern. Twelve species were captured in traps, and the remaining seven were documented by night-camera photography, pictures, and observations. Among relatively large forms, the presence of two species, the coyote (*Canis latrans*) and the bobcat (*Felis rufus*), was documented by night-camera photography, the American beaver (*Castor canadensis*) was

Table 2. Potential species that may occur and those documented in the 2003–2004 mammal survey in the Eastern Front and Five Forks units of Petersburg National Battlefield in Virginia.

Common Name	Literature[a]	Field Study[b]	
		Eastern Front	Five Forks
Virginia opossum	1,2,4,8,3	C,P	C,P
Pygmy shrew	1,4,6,8		C
Southeastern shrew	1,2,4,6,8		C
Northern short-tailed shrew	2,3		
Southern short-tailed shrew	1,2,4,6,7,8	C	C
Least shrew	1,2,4,6,8,3		
Eastern mole	1,2,4,8,3		
Star-nosed mole	1,2,4,6,8		
Eastern cottontail	1,2,4,8,3	O	O
Eastern chipmunk	1,2,4,8	C	
Woodchuck	1,2,4,8,3	O	O
Eastern gray squirrel	1,2,4,8,3	C,O	O
Fox squirrel	4		
Southern flying squirrel	1,2,4,8	O	
American beaver	1,2,4,8,3		O
Marsh rice rat	1,2,4,8,3		C
Eastern harvest mouse	1,2,4,8,3		
White-footed mouse	1,2,4,8	C	C
Golden mouse	2,4,8		C
Hispid cotton rat	2,4,6,8,3	C	C
Norway rat	1,2,8		
Black rat	1,2,3		
House mouse	1,2,8,3	O	C
Meadow vole	1,2,4,8		
Woodland vole	1,2,4,8,3		C
Common muskrat	1,2,4,8,3		
Meadow jumping mouse	1,2,4,8		
Coyote	1,4,8		P
Red fox	1,2,4,8,3	O	
Common gray fox	1,2,4,8	P	
Common raccoon	1,2,4,8,3	C,P	C,P
Long-tailed weasel	1,2,4,8		
Least weasel	1,6		
American mink	1,2,4,8,3		
Striped skunk	1,2,4,8,3	O	C
Northern river otter	1,2,4,8		
Bobcat	1,2,4		P
White-tailed deer	1,2,4,5,8,3	O	O

[a] Literature:
1. Bellows 2001a.
2. Handley and Patton 1927.
3. Jackson et al. 1976.
4. Linzey 1998.
5. NPSpecies 2005.
6. Pagels Unpublished Information.
7. Pagels and French 1987.
8. Webster et al. 1985.

[b] Field Study:
C. Captured
O. Observed
P. Photographed

Table 3. Number of captures (including recaptures) of each species* of mammals recorded within Petersburg National Battlefield during the 2003–2004 survey.

	Pitfall (16oz.)	Pitfall (2L)	Sherman	Small Tomahawk	Large Tomahawk	Night Photograph	Observation
Eastern Front Unit							
southern short-tailed shrew	14		11				
house mouse							X
white-footed mouse			118				
southern flying squirrel							X
eastern chipmunk			1				
hispid cotton rat			13				
eastern cottontail						1	X
eastern gray squirrel				4			X
domestic cat					6	1	X
striped skunk							X
woodchuck							X
Virginia opossum				3	16	11	
common raccoon				1	35	89	X
common gray fox						89	
red fox							X
white-tailed deer							X
Five Forks Unit							
pygmy shrew	1						
southeastern shrew	10	2	2				
southern short-tailed shrew	4	2	13				
woodland vole	1		2				
house mouse			1				
golden mouse		1	7				
white-footed mouse	3		335				
marsh rice rat			30	1			
hispid cotton rat			5	1			
eastern cottontail							X
eastern gray squirrel							X
domestic cat					1		
striped skunk				1	1		
northern river otter							X
woodchuck							X
Virginia opossum			1		11	25	
common raccoon					2	5	
American beaver							X
bobcat						1	
coyote						5	
white-tailed deer							X

* Species are arranged in increasing adult body length as approximated from Webster et al. (1985).

Table 4. Total number of species of mammals[a] captured in each habitat type surveyed in Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004.

	FFE[b]	PFP[b]	MPH[b]	HWD[b]	BLHWD[b]	WD[b]	Total
Eastern Front Unit							
Species							
Virginia opossum	3	7	3	2	4		19
southern short-tailed shrew	7	1	8	3	6		25
white-footed mouse	4	7	11	12	12		46
eastern chipmunk	1						1
eastern gray squirrel	1			1	1		3
hispid cotton rat	9				1		10
common raccoon	10	4	4	5	12		35
Total	35	19	26	23	36		139
Trapnights							
Pitfall	522	603	604	604	600		2,933
Sherman	592	699	671	727	689		3,378
Small Tomahawk	102	122	118	125	117		584
Large Tomahawk	53	59	63	63	59		297
Total	1,269	1,483	1,456	1,519	1,465		7,192
Richness	7	4	4	5	6		7
Evenness	0.87	0.88	0.91	0.80	0.82		0.82
Five Forks Unit							
Species							
Virginia opossum	2		1	3		5	11
pygmy shrew					1		1
southeastern shrew	3	3	7			1	14
southern short-tailed shrew	1	1	9		3	5	19
marsh rice rat				6	2	17	25
white-footed mouse	28	10	28	23	28	25	142
golden mouse	2	2			2	2	8
hispid cotton rat		1				4	5
house mouse			1				1
woodland vole				3			3
common raccoon	1			1			2
striped skunk	1			1			2
Total	38	17	46	37	36	59	233
Trapnights							
Pitfall	606	606	606	606	404	606	3,434
Sherman	710	744	716	699	489	731	4,089
Small Tomahawk	121	126	125	119	81	123	695
Large Tomahawk	60	62	60	61	41	63	347
Total	1,497	1,538	1,507	1,485	1,015	1,523	8,565
Richness	7	5	5	6	5	7	12
Evenness	0.53	0.75	0.67	0.67	0.51	0.77	0.58

[a]Species are arranged phylogenetically (after Jones et al. 1997).

[b]Abbreviations: FFE=Field-forest edge; PFP=Pine forest plantation; MPH=Mixed pine hardwood; HWD=Hardwood; BLHWD=Bottomland hardwood; WD=Wetland

Table 5. Average relative abundance (individuals per 100 trap[a] nights) of each species[b] of mammals captured within the different habitat types ± standard error, in Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004.

	FFE[c]	PFP[c]	MPH[c]	HWD[c]	BLHWD[c]	WD[c]
Eastern Front Unit						
Virginia opossum	1.9 ± 1.1	3.8 ± 2.2	1.7 ± 0.9	1.1 ± 0.5	2.3 ± 1.2	
southern short-tailed shrew	0.6 ± 0.3	0.1 ± 0.1	0.6 ± 0.3	0.2 ± 0.1	0.5 ± 0.1	
eastern chipmunk	0.2 ± 0.2					
eastern gray squirrel	1.0 ± 1.0			0.8 ± 0.8	0.8 ± 0.8	
white-footed mouse	0.7 ± 0.7	1.0 ± 0.1	1.6 ± 0.4	1.6 ± 0.7	1.7 ± 0.6	
hispid cotton rat	1.5 ± 0.9				0.1 ± 0.1	
common raccoon	18.8 ± 8.0	6.8 ± 1.6	6.3 ± 4.2	7.9 ± 3.2	20.9 ± 6.2	
Five Forks Unit						
Virginia opossum	1.1 ± 0.5		0.5 ± 0.5	1.7 ± 1.0		2.7 ± 1.4
pygmy shrew					0.2 ± 0.2	
southeastern shrew	0.5 ± 0.3	0.5 ± 0.3	1.2 ± 0.2			0.2 ± 0.2
southern short-tailed shrew	0.1 ± 0.1	0.1 ± 0.1	0.7 ± 0.3		0.3 ± 0.1	0.4 ± 0.3
marsh rice rat				0.9 ± 0.9	0.2 ± 0.2	2.3 ± 0.7
white-footed mouse	4.0 ± 1.0	1.3 ± 0.1	3.9 ± 0.5	3.4 ± 1.7	5.7 ± 0.8	3.4 ± 0.5
golden mouse	0.3 ± 0.3	0.3 ± 0.3			0.4 ± 0.4	0.3 ± 0.3
hispid cotton rat		0.1 ± 0.1				0.5 ± 0.4
house mouse			0.1 ± 0.1			
woodland vole				0.4 ± 0.3		
common raccoon	1.6 ± 1.6			1.8 ± 1.8		
striped skunk	1.6 ± 1.6			1.8 ± 1.8		

[a]Effort was determined from the trap types in which that species was captured.
[b]Species are arranged phylogenetically (after Jones et al. 1997).
[c]Abbreviations: FFE=Field-forest edge; PFP=Pine forest plantation; MPH=Mixed pine hardwood; HWD=Hardwood; BLHWD=Bottomland hardwood; WD=Wetland

documented on the basis of signs, and the river otter (*Lontra canadensis*) was observed (Table 3). The species and numbers of individuals recorded by each sampling method largely reflected the relative body size of the mammal (Table 3).

Two hundred and thirty-three mammals were captured in traps at Five Forks in 8,565 trapnights (Table 4). For each habitat type, the relative abundance, i.e. the number of individuals captured (M_{t+1}) corrected for trapping effort, is given for each species in Table 5. Similar to Eastern Front, overall trapping success and recapture rates at Five Forks were low during the survey, preventing a statistical comparison of differences in richness and relative abundance between habitat types. Even though overall richness (12) was reasonably high for species captured in traps, six species were represented by eight or fewer individuals. The white-footed mouse represented 61% of the mammals captured with 142 individuals trapped. In addition to the white-footed mouse, seven other species of small mammals were captured; one of those was a house mouse (*Mus musculus*). As was the case at Eastern Front, larger mammals, including the Virginia opossum, were marked to distinguish them in a given trapping session only and some of the individuals are likely recaptures from earlier sessions. Unlike Eastern Front, where numerous common raccoons were captured, only two common raccoons were captured at Five Forks, and the raccoon was also uncommon among mammals recorded in night photographs.

Richness of mammals captured ranged from five species to seven species among mammals captured in the six habitats sampled (Table 4). Of the 12 species captured, only the white-footed mouse was captured in all six habitats. The white-footed mouse comprised more than half the mammals captured in all habitat types except the wetland habitat type (WD) which yielded numerous marsh rice rats (*Oryzomys palustris*). Evenness of species among the habitats was strongly impacted, e.g., lowered, by the high numbers of white-footed mice that were captured.

Discussion

The number of species recorded at Eastern Front (15) represented only 40% of the potential species expected to occur there, and overall, suggested a relatively low mammal fauna for the unit. The number recorded at Five Forks (19), representing 50%, was somewhat higher. It is likely additional species may be present at both units, yet remain undetected. However, our potential list of 38 species for the Eastern Front and Five Forks units included mammal species that are rarely captured in mammal surveys, and that are infrequently observed by sign or direct sightings (Table 1). Species that we did not record and that are often not encountered include American mink (*Mustela vison*), long-tailed weasel (*Mustela frenata*), least weasel (*Mustela nivalis*), and black bear (*Ursus americanus*). These and other furbearing and game species are sometimes registered outside of National Park sites by fur trappers and hunters, or in parks as roadkills, but no such records were available for this inventory. The least weasel provides a good example of a species that may go undetected. The species was first collected in the Coastal Plain of Virginia only recently (Bellows et al. 1999a), and is now known to have a nearly statewide distribution. It is unlikely that the least weasel recently expanded its range into the Coastal Plain, but that it had previously gone undetected. Among small mammals, it is likely that both the eastern mole (*Scalopus aquaticus*) and the star-nosed mole (*Condylura cristata*) occur at Eastern Front and Five Forks, but only signs for one or both species were observed. The star-nosed mole is now known to have a nearly statewide distribution (Pagels, unpublished information).

Small mammals that inhabit old fields and edges in Virginia and that are sometimes common include the southeastern shrew (*Sorex longirostris*), least shrew (*Cryptotis parva*), eastern harvest mouse (*Reithrodontomys humulis)*, and eastern meadow vole (*Microtus pennsylvanicus*) (i.e., Jackson et al. 1976; Pagels 1977; Pagels et al. 1992; Bellows et al. 2001b). Although it is likely that these species occur somewhere in both Eastern Front and Five Forks, only the southeastern shrew was captured at Five Forks. Most of the species documented at Eastern Front and Five Forks are found in a variety of habitat types; i.e., they are habitat generalists. The only species captured at both Eastern Front and Five Forks that is typically associated with old fields or edges was the hispid cotton rat (Pagels et al. 1992). In Virginia the hispid cotton rat is often found associated with viny shrub growth in cold months and may move outside of such areas in warm months when warm season grasses, weedy plants, and legumes are nearby (Pagels 1977). Many of the old field mammal species noted above also prefer such heterogeneous old field habitats. Except for very spotty areas in some fields such habitat is nearly lacking at Eastern Front and Five Forks, and then it is largely limited to the narrow field-forest edges.

Unlike successional old fields, most fields at Eastern Front and Five Forks are characterized by exotic cool season grasses such as tall fescue (*Festuca arundinacea*) that provide poor habitat for small mammals (Indiana Division of Fish and Wildlife 2002). The Indiana Division of Fish and Wildlife (2002) report also summarized the following: Most fescues are aggressive, sod-forming grasses that create a thick, matted ground cover which severely limits the movement and foraging ability of ground-nesting and ground-feeding wildlife. In winter, the snow and ice may pack fescue grasses down even further. The thick matted growth form also prevents warm season grass seed from germinating. In addition, the Indiana report also notes that tall fescue is allellopathic; it inhibits the germination and establishment of other more beneficial plant species.

Delong and Brittingham (2001) observed that warm season grasses are much more hospitable to small mammals. They noted that tall bunch grasses provide adequate food for granivores, good cover from predators, and excellent runways and nesting sites. In a recent study in Bath County, VA, Mengak (2004) captured significantly more mammals in fields that had been chemically treated and burned and converted to warm season grasses than in fescue fields. Maintained and agricultural fescue fields are an obvious feature of the landscape of the units, largely to help interpret the Civil War cultural landscape of the park. Unfortunately, although fescues help to maintain the openness, they do little to encourage wildlife populations.

Even though similar habitat types exist within Eastern Front and Five Forks the units present widely contrasting landscapes in relation to the surrounding areas. Five Forks is continuous with the surrounding rural area in which it is located. The Eastern Front is similar to a peninsula that is largely encircled by a metropolitan area. A broad spectrum of wildlife would not occur in the area without the protection and habitats that are provided by Eastern Front. Conversely, the apparent low relative abundance and richness of mammals documented at Eastern Front likely reflect the popularity of this important historical area and the impact of the nearly encircling City of Petersburg. Domestic cats (*Felis catus*), pets that are allowed to wander, semi-dependent strays, and feral forms, are known predators of small mammals, birds, and other wildlife, and also compete with native mammalian and avian predators (Mitchell and Beck 1992; Coleman et al. 1997). Several domestic cats were captured, another was photographed, and it is likely that the species is abundant and an important predator at Eastern Front. Another species, the common raccoon, an opportunistic predator of many small mammals, including rodents and shrews, was also abundant at Eastern Front. The high numbers of common raccoons and domestic cats present on Eastern Front provide similar problems on public and private lands in many areas of the country. Unlike Eastern Front, the traps at Five Forks yielded only two raccoons, but our night cameras recorded both the coyote and the bobcat at Five Forks. The bobcat and coyote have been reported to prey on raccoons (Kaufman 1982). Additionally, there are numerous anecdotal accounts and many reports (i.e., Colona 2004) that indicate that the coyote also preys on the domestic cat.

Though we made no attempt to census the white-tailed deer, or to assess its impact on habitats, on the basis of sign and direct sightings, the species is very abundant at Eastern Front. The species' high abundance reflects the lack of natural predators and the absence of hunting within the park and in most areas around the park. White-tailed deer can alter both vegetation structure and composition; i.e., structure by reducing or severely degrading the understory, and composition by feeding on certain plants or seedlings more than others. Consequently, both browsing and grazing by deer also impact various wildlife species, including other mammal species and shrub- and ground-nesting birds. These impacts have been determined in many areas, including national parks (McShea et al. 1997; McShea and Rappole 2000). It is not known how changes in deer populations at PETE might affect mammal communities, but park managers should be aware of potential impacts that can be caused to wildlife and vegetation of the parks.

Japanese stiltgrass is recognized as a highly invasive, nonnative species throughout much of Virginia and other areas. The species spreads opportunistically, often in areas where the soil has been disturbed, and displaces native vegetation as the patch expands (Swearingen et al. 2002). Now found in many areas of the United States, Japanese stiltgrass will likely continue to expand its distribution at the expense of native plant species and other organisms that depend on native

species. It is likely that the impacts of Japanese stiltgrass on our results were negligible. However, in some low-lying areas, the understory in particular, may become a monoculture of stiltgrass in the future. Such a change would negatively impact wildlife that depend on native plants for food and cover.

Further, it is well understood that more than a single year of sampling is necessary to help ensure that meaningful and characteristic data are obtained. It is never known, for example, whether a single year or two or more reflect the status of populations or a population. It is unfortunate that 2002, the year prior to our first sampling sessions, was very dry, and the last of a three year drought in Virginia. Based on Richmond, VA records, which reflect the same weather patterns, the first sampling year (2003) was the second wettest on record. Precipitation in 2003 was 20 inches above a 109 year average and was the largest recorded departure from the average (NOAA 2004). Finally, in summers 2003 and 2004 remnants of hurricanes Isabel and Gaston, respectively, ravaged much of eastern Virginia with extreme rainfall and high winds. At Eastern Front especially, great numbers of both hardwood and conifer trees were uprooted by Isabel leaving numerous patches of blowdown. We will never know what impact these extreme conditions had on the current mammal inventories, but it is likely that fewer individuals of many species were captured than would have been captured in years with conditions closer to average. Over the short term, areas of blowdown in forests may temporarily benefit mammals as a result of increased herbaceous growth and increased seedlings as is often seen following clearcutting of forests (Kirkland 1990). Numerous rotting logs and woody debris will also benefit small mammals by providing suitable habitat.

Conclusions and Management Recommendations

Inventory Limitations and Additional Work

The list of mammals that potentially occur at Eastern Front and Five Forks included many species that were not detected in our surveys, and that we did not expect to document. The 15 species documented at Eastern Front suggests a relatively poor mammal fauna that likely reflects human impact on the area. The number at Five Forks, 19 species, is somewhat greater and likely reflects the rural nature of that unit. However, achieving no more that 50% of the expected species at either unit stresses the importance of considering several factors when developing potential species lists and interpreting survey results. Should additional surveys be desired by the NPS to add to the list of documented species, we suggest surveys that are directed toward a particular group of species (e.g., small or large mammals) or a certain habitat type. Such surveys would allow for more intense sampling, not require as many sampling techniques, and likely be more productive when sampling in short survey periods.

Further, if not already in place, a protocol should be developed for park personnel to report and assist in the documentation of mammals (and other wildlife) observed or the remains of animals that may be found in the park. Such animal remains may include, for example, unidentified road-killed animals, skulls or other bones, scats with bones, owl pellets, and whole specimens that may be collected. Kits that minimally include simple water-proof data sheets, pencils, and plastic storage bags, could be regularly carried in the park vehicles of selected personnel. A simple repository for temporary storage of such items can be the freezer compartment of a refrigerator that is not used for storage of food. Subsequently, arrangements can be made with a state museum (i.e., Virginia Museum of Natural History, or university museum) for identification of the specimens.

In addition, weather conditions must be considered when interpreting sampling results. Even though our study involved two field seasons, we feel that drought followed by extreme levels of precipitation negatively impacted our capture success.

Grassland Management

Conversion from cool to warm season grasses in Eastern Front and Five Forks fields would result in more natural heterogeneous old fields that would greatly benefit mammals while continuing to commemorate the battlefields cultural history. Managers at Eastern Front and Five Forks, perhaps in cooperation with local and state agricultural agencies, should develop a program for conversion and maintenance of converted old fields. Such a program will likely require mowing and, perhaps, prescribed burns, completed in a rotational fashion in selected portions of fields.

In hindsight, temporary “spot-trapping” of maintained and agricultural fields would have provided important baseline information as part of the field conversion, though we feel that it is unlikely that additional species would have been captured without intense sampling in many field areas. We suggest monitoring mammal populations in selected fescue fields in future conversions of fescue fields to more heterogeneous old fields. The monitoring should include both fescue fields and converted fields. Notable targets should be old field species such as the

hispid cotton rat and eastern meadow vole, as well as selected generalist species such as the northern short-tailed shrew and the white-footed mouse. Importantly, all of these species can be captured in Sherman live traps, i.e., they do not require the use of special sampling techniques.

Sampling Considerations

Our results support the importance of using multiple trap types and cameras in addition to actual observations (Table 3). Methods must target species of concern (i.e., pitfalls for small shrews, photographs for certain large species) to determine their presence and to measure management effectiveness. If geographic comparisons are a consideration for inventory and monitoring, the techniques used must be similar among different parks to allow for comparable results and to facilitate quantitative analyses (Mitchell et al. 1993).

Special Management Problems

The Eastern Front unit presents several management challenges, all of which reflect human activities in one way or another. The abundance of both the domestic cat and the common raccoon is predominantly a manifestation of human influences and it is likely that programs to lower their numbers will be difficult. The problem of overpopulation of the white-tailed deer and the species' impact on other wildlife and plants are well known to the NPS (for example, Cypher et al. 1988; Lovallo and Tzilkowski 2003; Storm et al. 1989). Attempts to control the numbers of any of these animals, notably the domestic cat and white-tailed deer, often become controversial and emotional issues (Soukup et al. 1999). Efforts to manage any of these species will necessarily involve the cooperative efforts of local, state, and federal agencies.

Literature Cited

Bellows, A. S., J. F. Pagels, and J. C. Mitchell. 1999a. First record of the least weasel, *Mustela nivalis* (Carnivore: Mustelidae), from the Coastal Plain of Virginia. Northeastern Naturalist 6:238-240.

Bellows, A. S., J. C. Mitchell, and J. F. Pagels. 1999b. Small mammal assemblages on Fort A. P. Hill, Virginia: habitat associations and patterns of capture success. Banisteria 14:3-15.

Bellows, A. S., J. C. Mitchell, J. F. Pagels, and H. N. Mansfield. 2001a. Mammals of Fort A. P. Hill, Caroline County, Virginia and vicinity. Virginia Journal of Science 52:163-226.

Bellows, A. S., J. F. Pagels and J. C. Mitchell. 2001b. Macrohabitat and microhabitat affinities of small mammals in a fragmented landscape on the upper Coastal Plain of Virginia. American Midland Naturalist 146:345-360.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Wildlife Management 39:388-394.

Colona, R. 2004. Coyotes in Maryland. Maryland Department of Natural Resources. www.dnr.state.md.us/wildlife/coyote.html

Cypher, B. L., Yahner, R. H., and Cypher, E. A. 1988. Seasonal food use by white-tailed deer at Valley Forge National Historical Park, Pennsylvania, USA. Environmental Management. 12:237-242.

Coleman, J. S., S. A. Temple, and S. R. Craven. 1997. Cats and Wildlife: A conservation dilemma. www.main.nc.us/nas-hpc/cats_and_wildlife a_conservation.htm

Delong, C., and M. Brittingham. 2001. Warm Season Grasses and Wildlife. Pennsylvania Wildlife 12:1-8. www.pa.nrcs.usda.gov/publications/warmseasongrasses.pdf

Handley, C. O., Jr., and C. P. Patton. 1947. Wild Mammals of Virginia. Virginia Commission of Game and Inland Fisheries, Richmond: 220.

Handley, C. O., Jr., and M. Varn. 1994. The trapline concept applied to pitfall arrays. Pp. 285-287 *In* J. F. Merritt, G. L. Kirkland, Jr., and R. K. Rose (eds), Advances in the biology of shrews. Carnegie Museum of Natural History Special Publication No. 18. Pittsburgh, PA.

Indiana Division of Fish and Wildlife. 2002. http://www.in.gov/dnr/fishwild/hunt/fescue.pdf

Jackson, S. R., J. F. Pagels, and D. N. Trumbo. 1976. The Mammals of Presquile, Chesterfield County, Virginia. Virginia Journal of Science 27:20-23.

Jones, C., R. S. Hoffmann, D. W. Rice, M. D. Engstrom, R. D. Bradley, D. J. Schmidly, C. A. Jones, and R. J. Baker. 1997. Revised checklist of North American mammals north of Mexico, 1997. Occas. Papers Mus., Texas Tech Univ. 62:1-17.

Kaufman, J. H. 1982. Raccoon and allies. Pages 567-585 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. Johns Hopkins University Press.

Kirkland, G. L., Jr. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. Oikos 59:313-320.

Kirkland, G. L., Jr., and P. K. Sheppard. 1994. Proposed standard protocol for sampling of small mammal communities. Pages 277-283 in J. F. Merritt, G. L. Kirkland, Jr., and R. K. Rose, editors. Advances in the biology of shrews. Special Publication of the Carnegie Museum of Natural History 18. Pittsburgh, PA.

Linzey, D. W. 1998. The Mammals of Virginia. The McDonald and Woodward Publishing Co. Blacksburg, VA.

Lovallo, M. J. and W. M. Tzilkowski. 2003. Abundance of white-tailed deer (*Odocoileus virginianus*) within Valley Forge National Historic Park and movements related to surrounding private lands. Technical Report NPS/NERCHAL/NRTR-03/091. National Park Service. Philadelphia, PA.

Mengak, M. T. 2004. Response of small mammal populations to fescue hayfield conversion to native warm season grasses in Bath County, Virginia. Virginia Journal of Science 55:169-176.

McShea, W. J., Underwood, H. B., and J. H. Rappole (editors). 1997. The Science of Overabundance: Deer Ecology and Population Management. Washington and London: Smithsonian Institution Press.

McShea, W. J. and J. H. Rappole. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. Conservation Biology 14(4):1161-1170.

McShea, W. J., J. Pagels, J. Orrock, E. Harper, and K. Koy. 2003. Mesic deciduous forest as patches of small-mammal richness within an Appalachian mountain forest. Journal of Mammalogy 84:627-643.

Mitchell, J. C., and R. A. Beck. 1992. Free-ranging domestic cat predation on native vertebrates in rural and urban Virginia. Virginia Journal of Science 43:197-207.

Mitchell, J. C., S. Y. Erdle, and J. F. Pagels. 1993. Evaluation of capture techniques for amphibian, reptile, and small mammal communities in saturated forested wetlands. Wetlands 13:130-136.

National Oceanic and Atmospheric Administration (NOAA). 2004(1). Virginia climate advisory. http://climate.virginia.edu/advisory/pdf/2004/ad04.01.pdf

Nelson, L., Jr., and E. W. Clarke. 1973. Correction for sprungtraps in catch/effort calculations of trapping results. Journal of Mammalogy 54:295-298.

NPSpecies. 2005. The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (accessed June 13, 2005).

Orrock, J. L., J. F. Pagels, W. J. McShea, and E. K. Harper. 2000. Predicting presence and abundance of a small mammal species: the effect of scale and resolution. Ecological Applications 10:1356-1366.

Pagels, J. F. 1977. Distribution and habitat of the cotton rat (*Sigmodon hispidus*) in central Virginia. Virginia Journal of Science 28:133-135.

Pagels, J. F., and T. W. French. 1987. Discarded bottles as a source of small mammal distribution data. American Midland Naturalist 118:217-219.

Pagels, J. F., S. Y. Erdle, K. L. Uthus, and J. C. Mitchell. 1992. Small mammal diversity in forested and clearcut habitats in the Virginia piedmont. Virginia Journal of Science, 43:171-176.

Pollock, K. H., J. D. Nichols, T. R. Simon, G. L. Farnsworth, L. L. Bailey, and J. R. Sauer. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. Environmetrics 13:105-119.

Silveira, L., A. T. A. Jacamo, and J. A. F. Diniz-Filho. 2003. Camera trap, line transect census and track surveys: a comparative evaluation. Biological Conservtion, 114:351-355.

Slade, N. A., and S. M. Blair. 2000. An empirical test of using counts of individuals captured as indices of population size. Journal of Mammalogy 81(4):1035-1045.

Soukup, M., Foley, M. K., Hiebert, R., and Huff, D. E. 1999. Wildlife management in U.S. National Parks: Natural regulation revisited. Ecological Applications. 9:1-2.

Storm, G. L., R. H. Yahner, D. F. Cottam, and G. M. Vecellio. 1989. Population status, movements, habitat use, and impact of white-tailed deer at Gettysburg National Military Park and Eisenhower National Historic Site. Technical Report NPS/MAR/NRTR-89/043. National Park Service. Philadelphia, PA.

Swearingen, J., K. Reshetiloff, B. Slattery, and S. Zwicker. 2002. Plant Invaders of Mid-Atlantic Natural Areas. National Park Service and U. S. Fish and Wildlife Service. Washington, DC.

Webster, W. D., J. F. Parnell, and W. C. Biggs Jr. 1985. Mammals of the Carolinas, Virginia, and Maryland. The University of North Carolina Press. Chapel Hill, NC.

Wilson, D. E., J. D. Nichols, R. Rudran, and C. Southwell. 1996. Introduction. Pages 1-7 *in* D. W. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Mammals. Smithsonian Institution Press, Washington.

Zar, J. H. 1999. Biostatistical Analysis. Fourth edition. Prentice-Hall, Inc. Upper Saddle River, NJ.

Appendix A. GPS locations* of all mammal trapping sites within Petersburg National Battlefield's Eastern Front unit, Petersburg, Virginia and Five Forks unit, Dinwiddie County, Virginia during the 2003–2004 inventory.

Eastern Front Unit			Five Forks Unit		
Site	Latitude (East)	Longitude (North)	Site	Latitude (East)	Longitude (North)
FFE 1	289929	4123426	FFE 1	267701	4113649
FFE 2	289665	4122049	FFE 2	267039	4114138
FFE 3	288864	4121581	FFE 3	267335	4113095
PFP 1	291281	4124075	PFP 1	267903	4114582
PFP 2	289519	4122295	PFP 2	267842	4113772
PFP 3	288959	4121918	PFP 3	266202	4113737
MPH 1	290657	4124251	MPH 1	265645	4113935
MPH 2	291095	4122747	MPH 2	267534	4113175
MPH 3	290018	4121821	MPH 3	267314	4113478
HWD 1	291251	4123680	HWD 1	267688	4113495
HWD 2	290722	4123089	HWD 2	266421	4114093
HWD 3	289971	4122186	HWD 3	267211	4112958
BLHWD 1	290524	4123617	BLHWD 1	268024	4114926
BLHWD 2	290861	4124005	BLHWD 2	267583	4114938
BLHWD 3	290220	4122898	WD 1	267882	4115020
			WD 2	267629	4115101
			WD 3	267493	4114567

*All readings are Universal Transverse Mercator (UTM), Zone 18, NAD83 in meters.

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004.

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area %
EF	FFE1	hackberry	*Celtis occidentalis*	16	0.728	33.2
		willow oak	*Quercus phellos*	30	0.646	29.5
		sweetgum	*Liquidambar styraciflua*	24	0.421	19.2
		red maple	*Acer rubrum*	6	0.236	10.8
		loblolly pine	*Pinus taeda*	13	0.114	5.2
		various dead spp.		3	0.037	1.7
		white oak	*Quercus alba*	1	0.010	0.4
EF	FFE2	black cherry	*Prunus serotina*	15	0.310	28.6
		loblolly pine	*Pinus taeda*	9	0.261	24.0
		sweetgum	*Liquidambar styraciflua*	10	0.258	23.8
		American sycamore	*Platanus occidentalis*	12	0.214	19.8
		red oak	*Quercus rubra*	1	0.015	1.4
		red cedar	*Juniperus virginiana*	1	0.013	1.2
		persimmon	*Diospyros virginiana*	1	0.006	0.6
		sassafras	*Sassafras albidum*	1	0.004	0.4
		white oak	*Quercus alba*	1	0.002	0.2
EF	FFE3	loblolly pine	*Pinus taeda*	45	1.329	56.1
		red cedar	*Juniperus virginiana*	30	0.604	25.5
		American sycamore	*Platanus occidentalis*	1	0.204	8.6
		sweetgum	*Liquidambar styraciflua*	9	0.194	8.2
		American hophornbeam	*Ostrya virginiana*	1	0.018	0.7
		willow oak	*Quercus phellos*	2	0.011	0.5
		sassafras	*Sassafras albidum*	1	0.005	0.2
		white oak	*Quercus alba*	1	0.004	0.2
EF	PFP1	loblolly pine	*Pinus taeda*	54	2.091	79.3
		sweetgum	*Liquidambar styraciflua*	46	0.312	11.8
		various dead spp.		10	0.096	3.7
		black cherry	*Prunus serotina*	3	0.081	3.1
		tulip poplar	*Liriodendron tulipfera*	2	0.056	2.1
EF	PFP2	loblolly pine	*Pinus taeda*	46	2.659	80.4
		various dead spp.		9	0.373	11.3
		sweetgum	*Liquidambar styraciflua*	46	0.167	5.1
		black cherry	*Prunus serotina*	6	0.066	2.0
		tulip poplar	*Liriodendron tulipfera*	4	0.023	0.7
		red cedar	*Juniperus virginiana*	1	0.008	0.2
		hackberry	*Celtis occidentalis*	1	0.005	0.2
		red oak	*Quercus rubra*	2	0.004	0.1
EF	PFP3	loblolly pine	*Pinus taeda*	51	2.957	91.7
		various dead spp.		4	0.089	2.8
		sweetgum	*Liquidambar styraciflua*	17	0.089	2.7
		red cedar	*Juniperus virginiana*	7	0.049	1.5
		black cherry	*Prunus serotina*	1	0.031	1.0
		mulberry	*Morus spp.*	1	0.005	0.2
		American holly	*Ilex opaca*	1	0.004	0.1

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area %
EF	MPH1	loblolly pine	*Pinus taeda*	8	1.316	37.8
		various dead spp.		8	0.776	22.3
		sweetgum	*Liquidambar styraciflua*	23	0.744	21.3
		hackberry	*Celtis occidentalis*	7	0.356	10.2
		willow oak	*Quercus phellos*	1	0.196	5.6
		elm	*Ulmus spp.*	6	0.050	1.4
		red maple	*Acer rubrum*	6	0.024	0.7
		tulip poplar	*Liriodendron tulipfera*	1	0.023	0.7
EF	MPH2	loblolly pine	*Pinus taeda*	8	1.329	43.4
		sweetgum	*Liquidambar styraciflua*	20	0.757	24.7
		various dead spp.		7	0.577	18.8
		tulip poplar	*Liriodendron tulipfera*	6	0.221	7.2
		butternut	*Juglans cinerea*	1	0.057	1.9
		mulberry	*Morus spp.*	3	0.049	1.6
		red oak	*Quercus rubra*	4	0.035	1.2
		American holly	*Ilex opaca*	6	0.015	0.5
		dogwood	*Cornus florida*	2	0.007	0.2
		ash	*Fraxinus spp.*	1	0.004	0.1
		black cherry	*Prunus serotina*	1	0.004	0.1
		white oak	*Quercus alba*	1	0.003	0.1
		hickory	*Carya spp.*	1	0.002	0.1
		ironwood	*Carpinus caroliniana*	1	0.002	0.1
EF	MPH3	loblolly pine	*Pinus taeda*	9	0.858	37.1
		red oak	*Quercus rubra*	2	0.703	30.4
		white oak	*Quercus alba*	7	0.418	18.1
		hickory	*Carya spp.*	5	0.152	6.6
		sweetgum	*Liquidambar styraciflua*	15	0.114	4.9
		tulip poplar	*Liriodendron tulipfera*	2	0.035	1.5
		American holly	*Ilex opaca*	1	0.018	0.8
		dogwood	*Cornus florida*	1	0.013	0.6
EF	HWD1	white oak	*Quercus alba*	8	1.398	84.3
		red oak	*Quercus rubra*	2	0.117	7.0
		blackgum	*Nyssa sylvatica*	4	0.032	1.9
		tulip poplar	*Liriodendron tulipfera*	2	0.031	1.9
		sweetgum	*Liquidambar styraciflua*	10	0.028	1.7
		various dead spp.		1	0.025	1.5
		dogwood	*Cornus florida*	4	0.017	1.0
		American holly	*Ilex opaca*	1	0.008	0.5
		sassafras	*Sassafras albidum*	1	0.003	0.2
EF	HWD2	red oak	*Quercus rubra*	5	0.967	47.9
		white oak	*Quercus alba*	10	0.915	45.4
		blackgum	*Nyssa sylvatica*	24	0.115	5.7
		sassafras	*Sassafras albidum*	3	0.009	0.4
		unknown "o"		1	0.005	0.2

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area %
		red maple	*Acer rubrum*	1	0.003	0.1
		dogwood	*Cornus florida*	1	0.002	0.1
		hickory	*Carya spp.*	1	0.002	0.1
EF	HWD3	white oak	*Quercus alba*	4	0.503	41.3
		red oak	*Quercus rubra*	4	0.236	19.4
		loblolly pine	*Pinus taeda*	1	0.181	14.9
		hickory	*Carya spp.*	7	0.136	11.2
		various dead spp.		3	0.091	7.5
		sweetgum	*Liquidambar styraciflua*	6	0.030	2.5
		tulip poplar	*Liriodendron tulipfera*	2	0.029	2.4
		American holly	*Ilex opaca*	1	0.005	0.4
		red maple	*Acer rubrum*	1	0.004	0.3
		blackgum	*Nyssa sylvatica*	1	0.002	0.2
EF	BLHWD1	sweetgum	*Liquidambar styraciflua*	6	1.714	57.7
		tulip poplar	*Liriodendron tulipfera*	6	1.039	35.0
		red maple	*Acer rubrum*	2	0.069	2.3
		American sycamore	*Platanus occidentalis*	1	0.062	2.1
		hackberry	*Celtis occidentalis*	8	0.052	1.8
		hickory	*Carya spp.*	1	0.015	0.5
		various dead spp.		1	0.011	0.4
		red oak	*Quercus rubra*	2	0.008	0.3
EF	BLHWD2	tulip poplar	*Liriodendron tulipfera*	3	0.652	50.8
		sweetgum	*Liquidambar styraciflua*	4	0.315	24.5
		ash	*Fraxinus spp.*	19	0.121	9.4
		blackgum	*Nyssa sylvatica*	1	0.108	8.4
		ironwood	*Carpinus caroliniana*	4	0.050	3.9
		American beech	*Fagus grandifolia*	3	0.018	1.4
		various dead spp.		1	0.010	0.7
		sweetbay	*Magnolia virginiana*	1	0.010	0.7
		American holly	*Ilex opaca*	1	0.002	0.2
EF	BLHWD3	tulip poplar	*Liriodendron tulipfera*	3	1.953	63.7
		American sycamore	*Platanus occidentalis*	4	0.569	18.5
		red maple	*Acer rubrum*	4	0.374	12.2
		sweetgum	*Liquidambar styraciflua*	12	0.071	2.3
		hackberry	*Celtis occidentalis*	11	0.050	1.6
		various dead spp.		1	0.049	1.6
FF	FFE1	red oak	*Quercus rubra*	9	0.834	31.7
		loblolly pine	*Pinus taeda*	11	0.565	21.5
		sweetgum	*Liquidambar styraciflua*	25	0.495	18.8
		white oak	*Quercus alba*	24	0.438	16.6
		hickory	*Carya spp.*	9	0.181	6.9
		blackgum	*Nyssa sylvatica*	3	0.055	2.1
		red cedar	*Juniperus virginiana*	3	0.021	0.8
		red maple	*Acer rubrum*	4	0.020	0.8

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area %
		American holly	*Ilex opaca*	3	0.015	0.6
		black cherry	*Prunus serotina*	1	0.005	0.2
		sassafras	*Sassafras albidum*	1	0.002	0.1
FF	FFE2	red maple	*Acer rubrum*	4	1.655	43.6
		loblolly pine	*Pinus taeda*	13	0.743	19.6
		white oak	*Quercus alba*	11	0.707	18.6
		sweetgum	*Liquidambar styraciflua*	30	0.502	13.2
		black cherry	*Prunus serotina*	9	0.106	2.8
		American holly	*Ilex opaca*	7	0.049	1.3
		red oak	*Quercus rubra*	2	0.014	0.4
		red cedar	*Juniperus virginiana*	3	0.009	0.2
		persimmon	*Diospyros virginiana*	2	0.004	0.1
		blackgum	*Nyssa sylvatica*	1	0.003	0.1
		hickory	*Carya spp.*	1	0.003	0.1
FF	FFE3	loblolly pine	*Pinus taeda*	50	1.102	65.7
		sweetgum	*Liquidambar styraciflua*	12	0.194	11.6
		red maple	*Acer rubrum*	3	0.159	9.5
		tulip poplar	*Liriodendron tulipfera*	1	0.075	4.5
		red cedar	*Juniperus virginiana*	9	0.071	4.2
		persimmon	*Diospyros virginiana*	1	0.031	1.9
		blackgum	*Nyssa sylvatica*	4	0.027	1.6
		white oak	*Quercus alba*	3	0.014	0.9
		American holly	*Ilex opaca*	1	0.002	0.1
FF	PFP1	loblolly pine	*Pinus taeda*	83	2.188	77.4
		tulip poplar	*Liriodendron tulipfera*	2	0.366	12.9
		red oak	*Quercus rubra*	20	0.116	4.1
		sweetgum	*Liquidambar styraciflua*	21	0.086	3.1
		white oak	*Quercus alba*	17	0.065	2.3
		red maple	*Acer rubrum*	2	0.007	0.2
FF	PFP2	loblolly pine	*Pinus taeda*	106	2.562	75.2
		red maple	*Acer rubrum*	11	0.377	11.1
		sweetgum	*Liquidambar styraciflua*	30	0.154	4.5
		white oak	*Quercus alba*	2	0.148	4.3
		snag	Various dead spp.	10	0.096	2.8
		tulip poplar	*Liriodendron tulipfera*	14	0.044	1.3
		blackgum	*Nyssa sylvatica*	2	0.013	0.4
		red oak	*Quercus rubra*	2	0.011	0.3
FF	PFP3	loblolly pine	*Pinus taeda*	52	2.364	75.2
		red oak	*Quercus rubra*	11	0.313	9.9
		white oak	*Quercus alba*	15	0.148	4.7
		snag	Various dead spp.	2	0.091	2.9
		red maple	*Acer rubrum*	10	0.084	2.7
		tulip poplar	*Liriodendron tulipfera*	18	0.076	2.4
		blackgum	*Nyssa sylvatica*	6	0.045	1.4

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area
		sweetgum	*Liquidambar styraciflua*	6	0.015	0.5
		American holly	*Ilex opaca*	5	0.010	0.3
FF	MPH1	loblolly pine	*Pinus taeda*	17	0.775	36.3
		white oak	*Quercus alba*	27	0.549	25.7
		red oak	*Quercus rubra*	16	0.284	13.3
		American holly	*Ilex opaca*	9	0.165	7.7
		red maple	*Acer rubrum*	3	0.112	5.2
		various dead spp.		12	0.086	4.0
		sweetgum	*Liquidambar styraciflua*	5	0.086	4.0
		tulip poplar	*Liriodendron tulipfera*	1	0.045	2.1
		red cedar	*Juniperus virginiana*	2	0.016	0.8
		blackgum	*Nyssa sylvatica*	1	0.011	0.5
		dogwood	*Cornus florida*	2	0.004	0.2
FF	MPH2	loblolly pine	*Pinus taeda*	24	2.062	69.2
		white oak	*Quercus alba*	9	0.409	13.7
		red maple	*Acer rubrum*	5	0.123	4.1
		sweetgum	*Liquidambar styraciflua*	7	0.120	4.0
		blackgum	*Nyssa sylvatica*	9	0.089	3.0
		tulip poplar	*Liriodendron tulipfera*	8	0.057	1.9
		American holly	*Ilex opaca*	7	0.054	1.8
		red oak	*Quercus rubra*	1	0.028	1.0
		sweetbay	*Magnolia virginiana*	1	0.028	1.0
		various dead spp.		2	0.009	0.3
FF	MPH3	loblolly pine	*Pinus taeda*	38	1.377	56.2
		white oak	*Quercus alba*	31	0.671	27.4
		red maple	*Acer rubrum*	11	0.170	6.9
		red oak	*Quercus rubra*	16	0.087	3.5
		American holly	*Ilex opaca*	5	0.070	2.9
		sweetgum	*Liquidambar styraciflua*	5	0.044	1.8
		blackgum	*Nyssa sylvatica*	6	0.025	1.0
		various dead spp.		2	0.004	0.2
		hickory	*Carya spp.*	1	0.003	0.1
FF	HWD1	white oak	*Quercus alba*	48	0.928	45.6
		tulip poplar	*Liriodendron tulipfera*	4	0.389	19.1
		hickory	*Carya spp.*	25	0.350	17.2
		red maple	*Acer rubrum*	6	0.154	7.6
		red oak	*Quercus rubra*	4	0.086	4.2
		blackgum	*Nyssa sylvatica*	2	0.083	4.1
		red cedar	*Juniperus virginiana*	4	0.029	1.4
		American holly	*Ilex opaca*	1	0.011	0.6
		sweetgum	*Liquidambar styraciflua*	2	0.006	0.3
FF	HWD2	red oak	*Quercus rubra*	34	1.274	48.2
		white oak	*Quercus alba*	33	0.785	29.7
		loblolly pine	*Pinus taeda*	6	0.236	8.9

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area
		sweetgum	*Liquidambar styraciflua*	13	0.147	5.6
		red maple	*Acer rubrum*	8	0.075	2.9
		hickory	*Carya spp.*	1	0.042	1.6
		dogwood	*Cornus florida*	4	0.035	1.3
		tulip poplar	*Liriodendron tulipfera*	6	0.027	1.0
		various dead spp.		2	0.011	0.4
		red cedar	*Juniperus virginiana*	1	0.008	0.3
		American holly	*Ilex opaca*	1	0.003	0.1
FF	HWD3	white oak	*Quercus alba*	33	1.108	50.4
		hickory	*Carya spp.*	12	0.402	18.3
		red maple	*Acer rubrum*	9	0.259	11.8
		red oak	*Quercus rubra*	6	0.096	4.3
		sweetbay	*Magnolia virginiana*	4	0.095	4.3
		sweetgum	*Liquidambar styraciflua*	17	0.091	4.1
		American holly	*Ilex opaca*	5	0.073	3.3
		blackgum	*Nyssa sylvatica*	5	0.072	3.3
		tulip poplar	*Liriodendron tulipfera*	1	0.003	0.1
		red cedar	*Juniperus virginiana*	1	0.002	0.1
FF	BLHWD1	tulip poplar	*Liriodendron tulipfera*	5	0.669	29.2
		birch	*Betula spp.*	2	0.410	17.9
		sweetgum	*Liquidambar styraciflua*	7	0.254	11.1
		red maple	*Acer rubrum*	5	0.247	10.8
		willow oak	*Quercus phellos*	1	0.159	6.9
		American holly	*Ilex opaca*	10	0.136	6.0
		red oak	*Quercus rubra*	7	0.116	5.1
		hickory	*Carya spp.*	5	0.107	4.7
		various dead spp.		4	0.093	4.0
		ironwood	*Carpinus caroliniana*	4	0.048	2.1
		sweetbay	*Magnolia virginiana*	1	0.025	1.1
		white oak	*Quercus alba*	2	0.010	0.4
		dogwood	*Cornus florida*	1	0.008	0.3
		blackgum	*Nyssa sylvatica*	2	0.007	0.3
FF	BLHWD2	red maple	*Acer rubrum*	16	2.110	75.2
		white oak	*Quercus alba*	4	0.181	6.5
		willow oak	*Quercus phellos*	1	0.173	6.2
		loblolly pine	*Pinus taeda*	6	0.079	2.8
		tulip poplar	*Liriodendron tulipfera*	1	0.071	2.5
		hackberry	*Celtis occidentalis*	3	0.066	2.4
		sweetgum	*Liquidambar styraciflua*	6	0.050	1.8
		blackgum	*Nyssa sylvatica*	3	0.050	1.8
		alder	*Alnus spp.*	2	0.010	0.4
		sweetbay	*Magnolia virginiana*	1	0.006	0.2
		American holly	*Ilex opaca*	1	0.005	0.2
		ash	*Fraxinus spp.*	2	0.005	0.2

Appendix B. Tree species and their contribution to the total basal area at each sampling site studied in the Eastern Front (EF) and Five Forks (FF) units of Petersburg National Battlefield, Virginia, documented during inventories conducted in 2003–2004 (continued).

Park Unit	Site	Common Name	Scientific Name	N	Basal Area (m^2)	Relative Basal Area
FF	WD1	red maple	*Acer rubrum*	7	0.805	36.5
		birch	*Betula spp.*	12	0.528	24.0
		various dead spp.		6	0.302	13.7
		hackberry	*Celtis occidentalis*	9	0.285	12.9
		sweetgum	*Liquidambar styraciflua*	3	0.104	4.7
		ironwood	*Carpinus caroliniana*	5	0.076	3.4
		white oak	*Quercus alba*	2	0.059	2.7
		blackgum	*Nyssa sylvatica*	2	0.018	0.8
		red oak	*Quercus rubra*	1	0.013	0.6
		American holly	*Ilex opaca*	2	0.008	0.3
		willow oak	*Quercus phellos*	1	0.006	0.3
FF	WD2	red maple	*Acer rubrum*	21	1.060	64.7
		willow oak	*Quercus phellos*	6	0.188	11.5
		hackberry	*Celtis occidentalis*	1	0.159	9.7
		sweetgum	*Liquidambar styraciflua*	3	0.086	5.2
		tulip poplar	*Liriodendron tulipfera*	2	0.069	4.2
		blackgum	*Nyssa sylvatica*	2	0.025	1.5
		white oak	*Quercus alba*	3	0.023	1.4
		alder	*Alnus spp.*	1	0.018	1.1
		persimmon	*Diospyros virginiana*	1	0.010	0.6
		sweetbay	*Magnolia virginiana*	1	0.002	0.1
FF	WD3	red maple	*Acer rubrum*	33	2.172	87.8
		various dead spp.		2	0.170	6.9
		white oak	*Quercus alba*	2	0.075	3.0
		willow oak	*Quercus phellos*	2	0.026	1.0
		blackgum	*Nyssa sylvatica*	1	0.011	0.5
		persimmon	*Diospyros virginiana*	1	0.011	0.5
		American sycamore	*Platanus occidentalis*	1	0.010	0.4

FFE=Field-forest Edge
PFP=Pine Forest Plantation
MPH=Mixed Pine Hardwood
HWD=Hardwood
BLHWD=Bottomland Hardwood
WD=Wetland

Appendix C. Number of trapnights for each trap type during each seasonal trapping period at Petersburg National Battlefield, Virginia.

Trap Type	Number of Trapnights				
	Summer	Fall	Winter	Spring	Summer
Eastern Front Unit	3-6 June, 14-18 July 2003	17-19 Oct. 2003	8-11 Jan. 2004	16-18 April 2004	7-11 June, 12-16 July 2004
Pitfall	768	240	450	284	1,191
Sherman	1,087	340	357	321	1,273
Sm. Tomahawk	184	56	60	57	227
Lg. Tomahawk	93	27	30	29	118
Camera	0	6	6	6	24
Five Forks Unit	10-13 June, 21-25 July 2003	24-26 Oct. 2003	14-16 Jan. 2004	23-25 April 2004	14-18 June, 19-23 July 2004
Pitfall	952	272	510	340	1,360
Sherman	1,399	389	396	391	1,514
Sm. Tomahawk	235	64	66	67	263
Lg. Tomahawk	119	33	32	34	132
Camera	0	6	6	6	24

Appendix D. Number of trapnights per trap type at each trapping site within Petersburg National Battlefield, Virginia, between May 2003 and September 2004.

	Number of Trapnights Habitat Type and Site Number																	
Trap Type	FFE1	FFE2	FFE3	PFP1	PFP2	PFP3	MPH1	MPH2	MPH3	HWD1	HWD2	HWD3	BLHWD1	BLHWD2	BLHWD3	WD1	WD2	WD3
Eastern Front																		
Pitfall	174	170	178	202	200	201	200	202	202	202	200	202	200	202	198			
Sherman	200	195	197	238	229	232	224	235	212	233	248	246	212	242	235			
Sm. Tom.	32	35	35	41	42	39	40	42	36	42	42	41	36	42	39			
Lg. Tom	18	18	17	20	20	19	21	21	21	21	21	21	18	21	20			
Total	424	418	427	501	491	491	485	500	471	498	511	510	466	507	492			
Total per Habitat Type		1,269			1,483			1,456			1,519			1,465				
Five Forks																		
Pitfall	202	202	202	202	202	202	202	202	202	202	202	202	202	202		202	202	202
Sherman	244	222	244	249	248	247	236	233	247	234	243	222	244	245		250	236	245
Sm. Tom.	41	39	41	42	42	42	42	41	42	39	42	38	39	42		42	41	40
Lg. Tom	21	18	21	21	21	20	21	21	21	21	21	19	20	21		21	21	21
Total	508	481	508	514	513	511	501	497	512	496	508	481	505	510		515	500	508
Total per Habitat Type		1,497			1,538			1,510			1,485			1,015			1,523	

FFE=Field-forest Edge
PFP=Pine Forest Plantation
MPH=Mixed Pine Hardwood
HWD=Hardwood
BLHWD=Bottomland Hardwood
WD=Wetland

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-92 November 2005

National Park Service
U.S. Department of the Interior

Northeast Region
Natural Resource Stewardship and Science
200 Chestnut Street
Philadelphia, Pennsylvania 19106-2878

http://www.nps.gov/nero/science/